



Make Any Home Appliance Into a Solar Electric Hybrid

Written By: Jason Poel Smith



TOOLS:

- [Soldering iron \(1\)](#)
- [Wire stripper/crimper \(1\)](#)
- [power drill and bit set \(1\)](#)
- [screwdriver set \(1\)](#)

SUMMARY

Here is a video summarizing the project

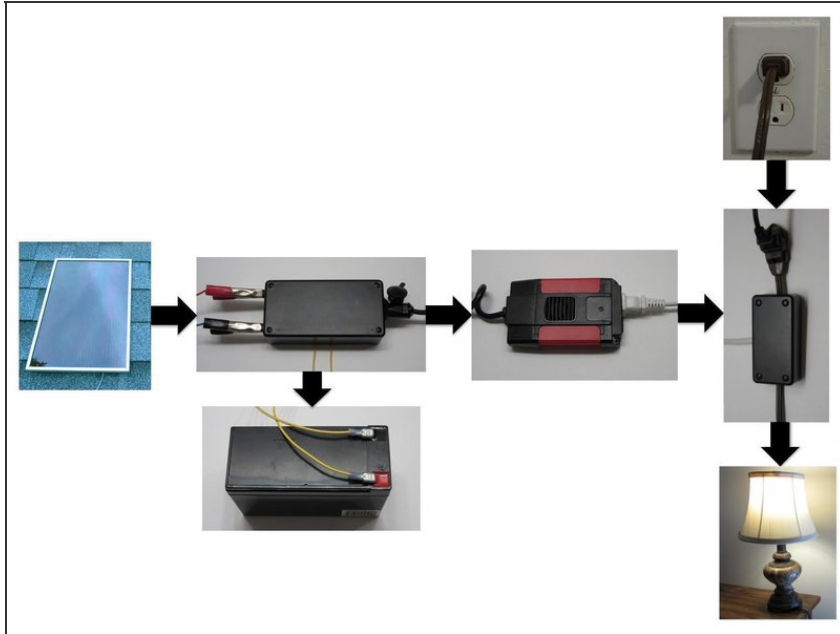
Step 1 — Introduction



- This project is a simple and cheap way to integrate renewable energy into your home by turning your appliances into solar electric hybrids.
- Here is how it works. A solar panel charges a storage battery. A control circuit monitors the battery's voltage. When the battery is fully charged, the circuit automatically turns on a power inverter and switches the appliance from running on grid power to running on the energy stored in the battery.
- Then when the battery's voltage drops too low, the circuit automatically switches the appliance back to grid power until the battery is recharged.
- This design doesn't require any modification to the appliance or your home's electrical system. It can work with any power source that is capable of charging a 12V battery (examples: wind turbines, bike generators, etc.).
- But most importantly the system is scalable. This design is set up for outputs of up to 75 watts, but by swapping out parts for ones with higher power ratings you can power larger appliances or multiple smaller appliances at the same time. This lets you build a system

that fits your energy needs and your budget.

Step 2 — System Overview



- Here are the five basic parts of this system: 1. 12V Solar Panel (or other renewable power source) 2. 12V Rechargeable Battery 3. Control Circuit 4. 12V Power Inverter 5. Automatic Switching Circuit
- When assembled, the solar panel, battery, and inverter plug into the control circuit. The automatic switching circuit plugs into the inverter and the wall outlet. Then the appliance plugs into the automatic switching circuit.
- The solar panel, battery, and inverter may be purchased off-the-shelf from a variety of locations. The last two parts of the system (the control circuit and the automatic switching circuit) will need to be constructed. This is detailed in later steps.

Step 3 — Choose a Solar Panel



- The solar panel that I used was a 5 watt model from Harbor Freight. The only difference that the power output makes is how quickly the battery will charge and how often the system will be activated. The only guideline to follow is that you don't want a panel that produces more power than you will use in a day. This would result in wasted energy.
- Keep in mind that other power sources can be used in place of the solar panel. Wind and bicycle generator could also work well. They just have to be capable of charging a 12 volt battery.

Step 4 — Choose a Battery



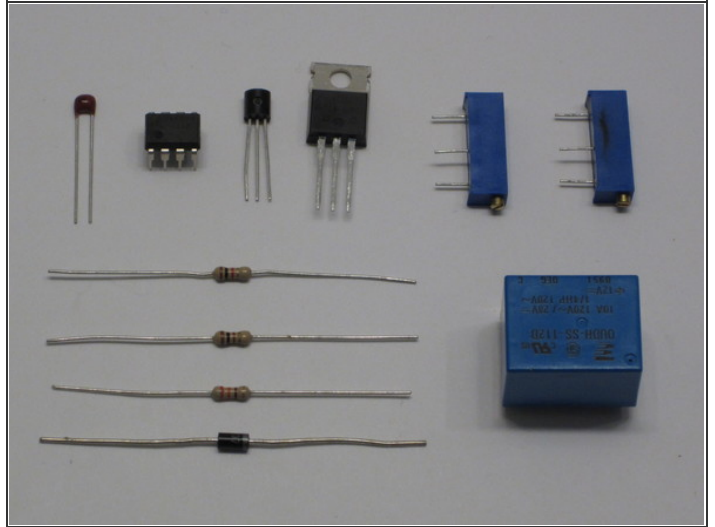
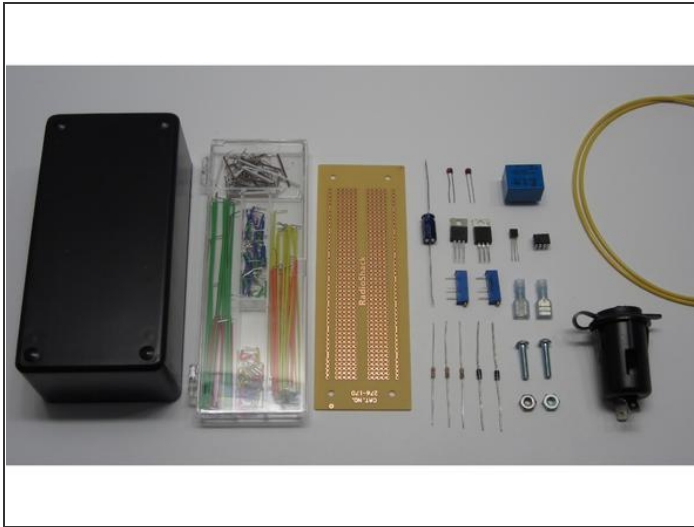
- When selecting a battery you have some trade-offs to consider. Batteries are more efficient and last longer when they are charged and discharged slowly. It is also best to minimize how deeply you discharge the battery.
- As a result, bigger batteries will give better performance. But larger batteries are more expensive and take up more space. Deep cycle batteries are better at withstanding the regular charging and discharging experienced as part of a solar electrical system. But deep cycle batteries are also more expensive.
- I am using a 7Ah battery to power a 13 watt CFL lamp for my finch aviary. This seems to work well. If you are confused about which battery to buy, it might help to consult the battery expert at your local store. They should be able to recommend a battery for your application and budget.

Step 5 — Choose a Power Inverter



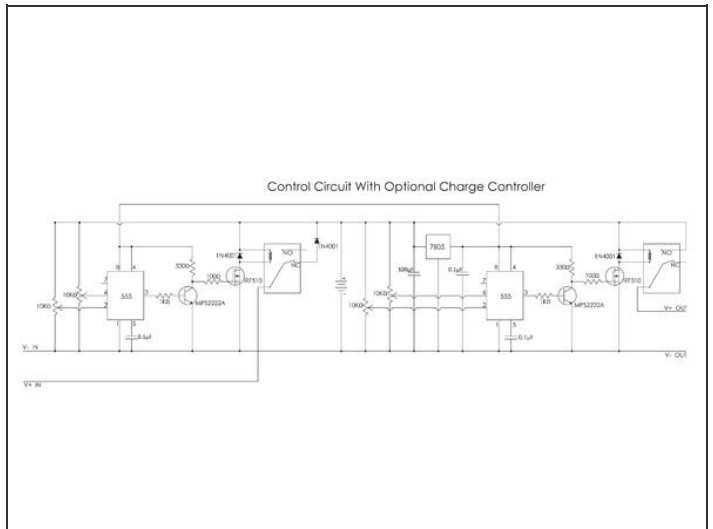
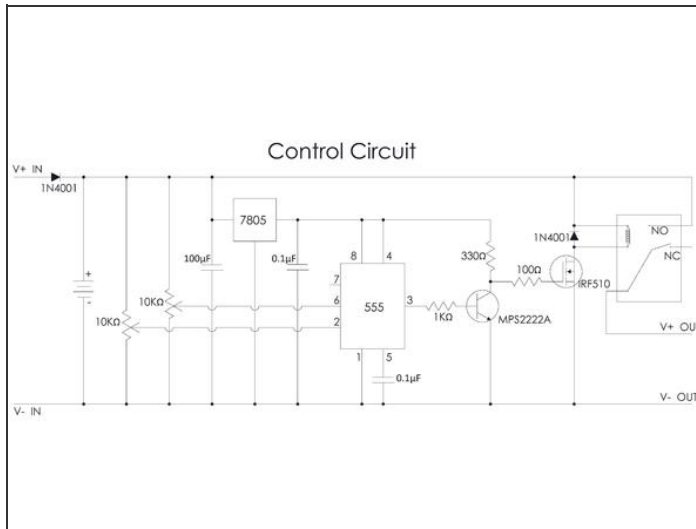
- The power inverter converts the output of your 12V DC battery into 120V AC that can power home electronics. I am using an 80 watt model from Harbor Freight. The most important requirement for your power inverter is that it must be capable of continuously powering the appliance(s) that you want to run.
- Inverters generally list their maximum power ratings in terms of both continuous and peak watts. Generally you want to stay a bit under the continuous limit to avoid excessive heating.

Step 6 — Control Circuit Materials



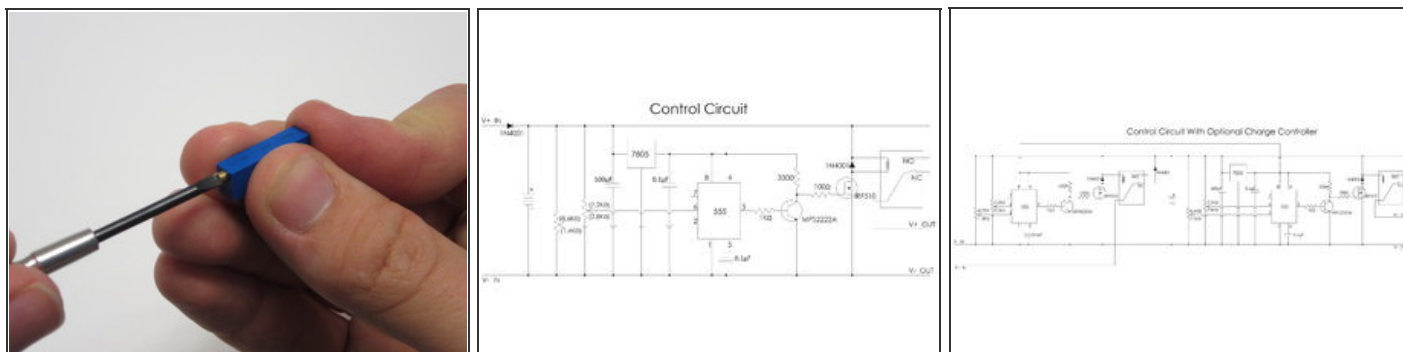
- Printed Circuit Board (Radio Shack #276-170) 2 x Diode (Radio Shack #276-1103) +5V Fixed-Voltage Regulator (Radio Shack #276-1770) 555 timer IC (Radio Shack # 276-1723) MPS2222A NPN Transistor (Radio Shack #276-2009) IRF510 MOSFET (Radio Shack # 276-2072)
- 100μF 15V Capacitor (optional) 2 x 0.1μF 15V Capacitor (optional) 2 x 10K-Ohm 15-Turn Cermet Potentiometer/Trimmer (Radio Shack #271-343) 100-Ohm Resistor (Radio Shack #271-005) 330-Ohm Resistor (Radio Shack #271-012) 1K-Ohm Resistor (Radio Shack #271-004) 12VDC/125VAC 10A SPDT Mini Relay (Radio Shack #275-248)
- 12VDC Vehicle Power Accessory Outlet (Radio Shack #270-046) Project Enclosure (6x3x2") (Radio Shack #270-1805) 2 x bolts (1/4" or smaller) 2 x nuts (1/4" or smaller) 2 x 1/4" Fully Insulated Female Quick Disconnects (Radio Shack #64-3133) 2 ft. x 16 gauge wire Jumper Wires
- Part Substitutions: I chose these parts because they are easily accessible (most can be purchased from Radio Shack). However, all of them may be substituted for other parts with similar values. You can generally find them cheaper online.
- The trimmer potentiometers may be replaced with single turn potentiometers or fixed value resistors. I chose these potentiometers because it is easier to make fine adjustments when calibrating the circuit. The input diode can be replaced with a schottky diode for better performance.
- Optional Charge Controller Materials: Diode (Radio Shack #276-1103) 555 timer IC (Radio Shack # 276-1723) 0.1μF 15V Capacitor (optional) MPS2222A NPN Transistor (Radio Shack #276-2009) IRF510 MOSFET (Radio Shack # 276-2072)
- Optional Charge Controller Materials cont.: 2 x 10K-Ohm 15-Turn Cermet Potentiometer/Trimmer (Radio Shack #271-343) 100-Ohm Resistor (Radio Shack #271-005) 330-Ohm Resistor (Radio Shack #271-012) 1K-Ohm Resistor (Radio Shack #271-004) 12VDC/125VAC 10A SPDT Mini Relay (Radio Shack #275-248)

Step 7 — Control Circuit Design



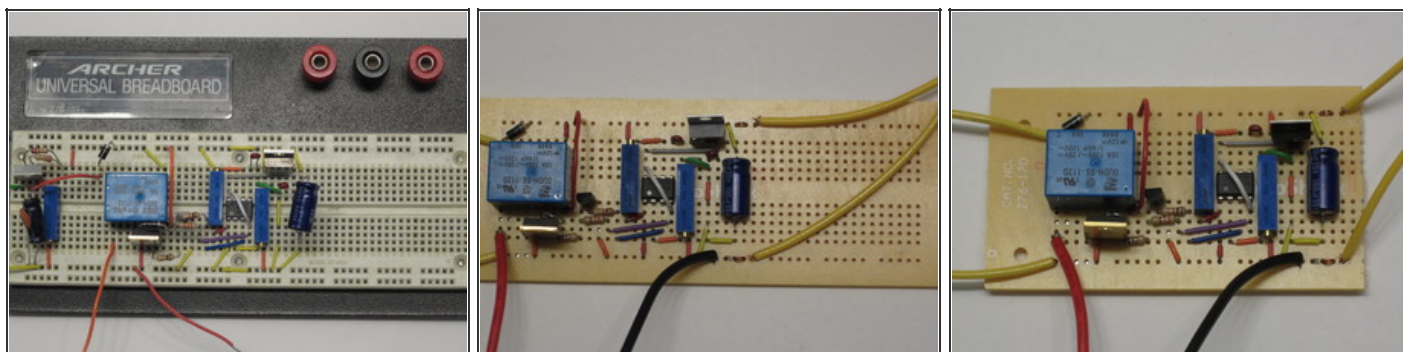
- This circuit is a modified version of a charge controller circuit that was designed by Mike Davis (<http://www.mdpub.com/555Controller/index...>).
- In the original circuit, a 555 timer IC was used to disconnect a battery from the solar panel when its voltage gets too high (to prevent it from over charging). In my design, the control circuit connects the battery to an inverter and an output circuit when the battery is fully charged.
- Here is a brief description of how the circuit works. A 5V voltage regulator powers the 555 timer IC and sets its internal reference voltages. A pair of potentiometers (variable resistors) are set up as voltage dividers that provide a signal to the timer IC that is proportional to the battery's voltage.
- These signals determine the operating range of the system. As the battery's voltage rises and falls, so does the output signals of the potentiometers. When the signal at pin 6 rises above 3.3V, the output of the IC goes LOW and activates the relay through a series of transistors.
- When the signal at pin 2 falls below 1.6V, the output of the IC goes HIGH, which deactivates the relay. By setting the positions of the potentiometers, you determine at what voltages the battery must be to activate and deactivate the output.
- Alternate Design with Charge Controller A charge controller usually isn't required for this setup. If the output of your solar panel is small relative to the storage capacity of your battery and you are powering a device that is frequently turned on, then you generally don't need to be worried about over charging the battery.
- However, if you wish to use a charge controller, you may attach one between the solar panel and the control circuit. I have also provided an alternate circuit design that includes a charge controller built into the control circuit.

Step 8 — Preset the Potentiometers



- Before assembling the circuit, it is a good idea to preset the potentiometers. This will prevent a lot of troubleshooting later. As indicated in the pictures, the values of the potentiometers should be set to the following:
- Basic Control Circuit Design Potentiometer connected to pin 2: 8600Ω between wiper and the positive rail, and 1400Ω between wiper and the negative rail. Potentiometer connected to pin 6: 7200Ω between wiper and the positive rail, and 2800Ω between wiper and the negative rail.
- Optional Charge Controller Potentiometer connected to pin 2: 8700Ω between wiper and the positive rail, and 1300Ω between wiper and the negative rail. Potentiometer connected to pin 6: 7500Ω between wiper and the positive rail, and 2500Ω between wiper and the negative rail.
- These will not be the final calibrated values. These are just convenient starting locations to get you in the ball park. The final settings will depend on the specific battery that you are using and its recommended operating range.
- When making the final adjustments, it is helpful to use a power supply with an adjustable voltage regulator such as a LM317T (Radio Shack #276-1778). See the following step for an example. If you don't have access to an adjustable power supply it will take a bit of time tweaking the values and checking it with a multimeter.

Step 9 — Control Circuit Assembly



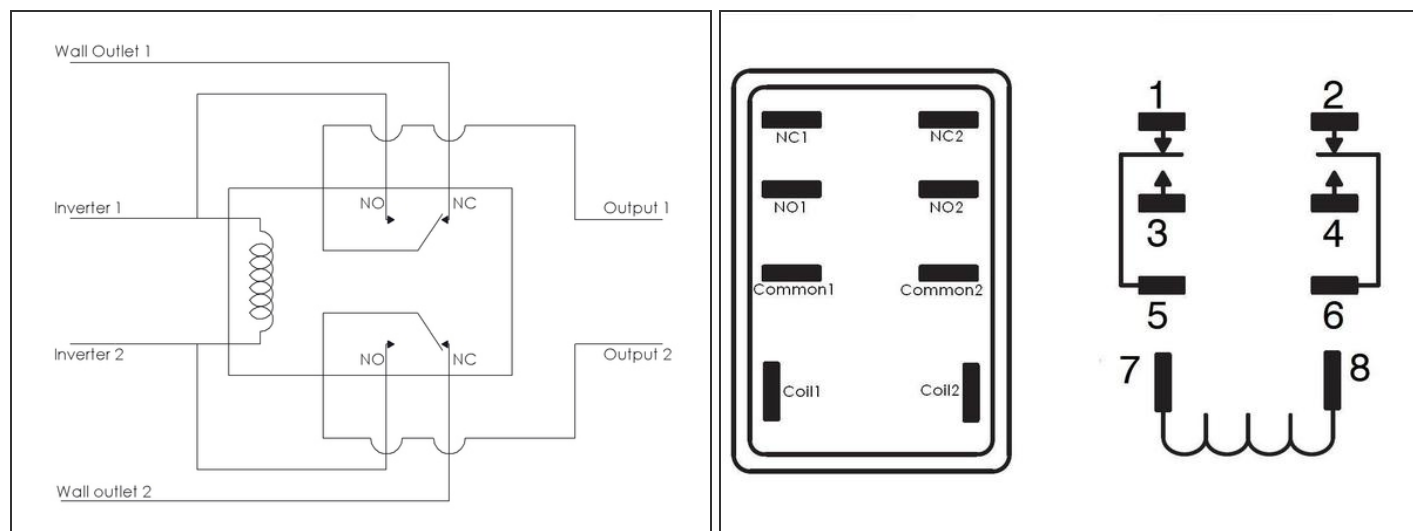
- Always prototype circuits on a breadboard before soldering them onto a printed circuit board. In my breadboard prototype, I included an adjustable voltage regulator so that I could quickly simulate the charging and discharging cycles. This makes it convenient to work out the final adjustments to the potentiometers.
- If you are using the same boards that I am, you can just copy my layout. The PCB is a bit longer than it needs to be for this circuit. To trim off the excess, use a sharp knife to deeply score a line across the board through one column of holes and break it off along the line.

Step 10 — Automatic Switching Circuit Materials



- Automatic Switching Circuit
Materials: Project Enclosure (Radio Shack #270-1801) 125VAC/10A DPDT Plug-In Relay (Radio Shack #275-217) 8 x 1/4" Fully Insulated Female Quick Disconnects (Radio Shack #64-3133) 1 full extension cord with male and female ends 1 power cord with male end only (preferably a different color than the extension cord)
- Tools: Wire Strippers Crimping Tool (for quick disconnects) Knife or Dremel (for cutting housing)

Step 11 — Automatic Switching Circuit Design



- This circuit has only one major part: a double pole double throw relay. It is wired in such a way that it will automatically switch the output whenever the inverter is powered on.
- To achieve this, the input line from the wall outlet is connected to the normally closed contacts and the output line going to the appliance is connected to the common contacts. Then the input line from the inverter is connected to both the coil and the normally open contacts.
- When the device is inactive, your appliance will be connected to the wall outlet and powered by the grid as it normally would be. The only difference is that it is going through the relay. But when the device is activated, the inverter turns on and sends power to the normally open contacts and the coil.
- This switches the relay. The appliance is disconnected from the wall outlet and connected to the inverter. This is how the switching circuit will automatically switch to your renewable power source whenever it is available.

Step 12 — Automatic Switching Circuit Assembly



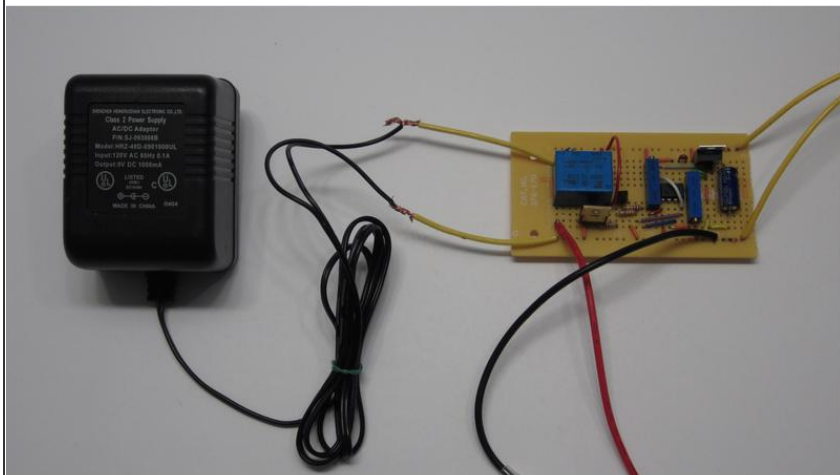
- Begin by cutting the extension cord into two pieces. The female end will be the output line where the appliance is plugged in. The male end will be the grid input line that is plugged into the wall outlet. The second power cord will be the input line that is plugged into the inverter.
- You may wish to select a power cord for the inverter line that is a different color than the other cords. This helps prevent mixing up the lines. You may also want to label them.
- Cut a 3 inch section off the end of the inverter power cord. This will be the jumper between the coil contacts and the normally open contacts on the relay. Strip 1/2 inch of insulation from the ends of all the wires.
- Twist together the exposed ends of the inverter cord and the 3 inch section that you just made and crimp them into a single pair of quick disconnects as shown in the picture. Then crimp quick disconnects onto all the remaining wire ends. Connect the output line (female end of the extension cord) to the common terminals.
- Connect the grid input line (male end of the extension cord) to the normally closed terminals. Lastly, connect the first set of quick disconnects on the inverter input line to the coil terminals and connect the second pair quick disconnects to the normally open terminals.

Step 13 — Project Housing Modifications



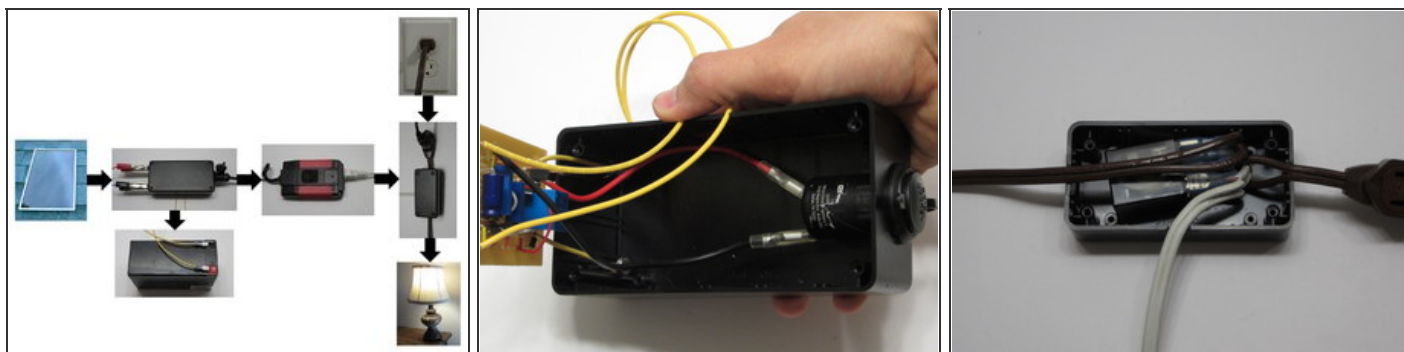
- **Solar Panel Attachment Point** The cables from my solar panel have clamps on the end. So I decided to use bolts as the attachment points on the control circuit housing. For this, I found a pair of bolts and nuts that fit the clamps.
- Then I drilled holes in the side of the housing that were a little smaller than the bolts and screwed the bolts into the holes. The nuts were threaded onto the bolt inside the housing. This will make the attachment point for the wires inside the housing.
- **Holes for Wires** Because so many quick disconnects are used, it would be inconvenient to feed the wires into the enclosures through drilled holes. Instead, I found it easier to just cut small slits in the side of the enclosure where the two halves come together. Do this for all the wires that go through the walls of the enclosures.
- **DC Power Outlet Hole** Drill or cut a 1 3/32" hole in the side of the housing for the control circuit. Since this is an odd size, you will probably have to drill a 1" hole and widen the hole with a file or knife. Insert the DC power outlet into the hole. If it doesn't fit tightly, you can secure it in place with glue.

Step 14 — Optional Testing With a DC Power Supply



- Since a system that is solar powered is most active in the middle of the day (when many people are at work), it can be inconvenient to do initial testing and observation of the system at work. To get around this, you may wish to use a DC power supply in place of the solar panel for initial testing.
- The simplest and cheapest way to do this is to use an DC power adapter. Find one that has a operating voltage of about 12V. The open circuit voltage (no load) will usually be a good bit higher. The exact type doesn't matter. You probably have a suitable DC power adapter lying around your house somewhere.
- You may wish to add a capacitor between the positive and negative terminals if the power supply doesn't have a steady output. Connect the positive wire from the power supply to the positive terminal of the control circuit and the negative wire to the negative terminal of the control circuit.
- This will charge the battery and function just as the panel would, but isn't dependent on sunlight. This can make it more convenient to monitor performance and troubleshoot the initial setup.

Step 15 — Finished Assembly



- Be sure to test all parts of the system individually before assembling them together.
- Attach the clamps from the solar panel onto the bolts on the control circuit housing. Then attach the input wires on the control circuit board to the bolts on the inside the housing and tighten the nuts to hold them in place. Attach the battery lines on the control circuit to the corresponding battery terminals.
- Be careful not to mix up the positive and negative wires! You probably want to label them or color code them. Attach the output lines on the control circuit to the DC power outlet. Be sure to attach the positive wire to the center pin and the negative wire to the outer barrel. Once everything is in place, close up the housing.
- Attach the inverter by plugging it into the DC power outlet. Put the automatic switching circuit into its housing and close it up. Then plug the inverter power cord into the inverter. Plug the appliance into the output line. If the battery was fully charged, the appliance should be powered. Lastly plug the wall outlet power cord into a wall outlet.
- Carefully observe all the parts of the system to make sure that nothing is making any weird sounds, smells, or is catching on fire. If not, you have a functioning solar electric hybrid adapter.

Step 16 — Final Notes and Future Design Improvements



- **Final Notes and Warnings:** The operation of this device involves regularly cutting power and switching to a second power source that may be out of phase. As a result, the output may momentarily fluctuate. This is especially true if your switching circuit uses a relay with a low activation voltage.
- In this case, the relay might switch before the inverter is running at full power. This momentary fluctuation is no problem for simple appliances like a lamp or fan, but may potentially cause problems for sensitive electronics. So choose your appliances carefully. I am not responsible if you fry your computer.
- **Future Design Improvements:** The biggest problem with this design is that the device activates as soon as the battery is fully charged. This does not necessarily coincide with when the appliance is turned on. Even if no appliance is on, the relays and the inverter will still consume power.
- In a future design, I will combine the various parts of this project into a single unit that has a sensor to determine when the appliance is turned on. Only once the appliance is turned on will the control circuit activate the relays and the inverter.

This will help ensure that less power is wasted.

- I would also like to add something to the circuit to smooth the output of the system to avoid the power fluctuations mentioned above. This might be something as simple as adding a time delay on the switching circuit.
- If you have any suggestions for improvements please leave a comment and let me know.

This project is a cheap way to integrate solar power into your home.

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